oxygen concentrations below 5 mg/L in bottom waters as being in fair condition (i.e., threatened). About 24% of bottom waters have dissolved oxygen concentrations below 5 mg/L (Figure 2-9). Northeast Coast estuaries showed the greatest number of locations experiencing low dissolved oxygen.

The NCA surveys measure dissolved oxygen conditions only in estuarine waters and do not include observations of dissolved oxygen concentrations in offshore coastal shelf waters. The occurrence of hypoxia in Gulf of Mexico shelf waters is a well-known and documented phenomenon. The Gulf of Mexico hypoxic zone is the largest zone of anthropogenic coastal hypoxia in the Western Hemisphere (CAST, 1999). Between 1989 and 1999, midsummer bottom-waters hypoxia increased to include nearly 8,000 square miles. In 2000 (the year of the Gulf of Mexico survey), the hypoxic zone was greatly reduced to less than 1,800 square miles; however, the hypoxic zone returned to about 8,000 square miles in 2001. The reduction in the size of the zone in 2000 corresponds to severe drought conditions in the Mississippi River watershed and, presumably, decreased flow and loading to the Gulf of Mexico from the river mouth. A complete discussion of the hypoxic zone is provided in Chapter 5, Gulf of Mexico Coastal Condition.

Interpretation of Instantaneous Dissolved Oxygen Information

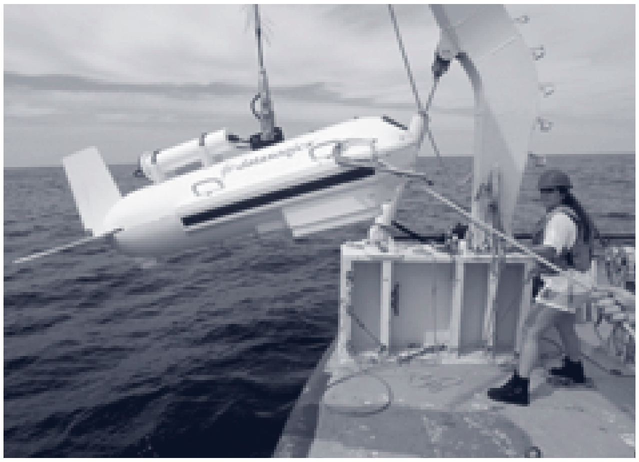
Although NCA survey results do not suggest that dissolved oxygen concentrations are a pervasive problem, the instantaneous measurements on which these results are based may have underestimated the magnitude and duration of low dissolved oxygen events at any given site. Longer-term observations by other investigators have revealed increasing trends in frequency and areal extent of low-oxygen events in some coastal areas. For example, extensive year-round or seasonal monitoring data over multiple years in such places as the Neuse and Pamlico rivers in North Carolina and the Narragansett Bay in Rhode Island (see Highlight in Chapter 3) have shown a much higher incidence of hypoxia than is depicted in the present NCA data. These data show that while hypoxic conditions do not exist continuously, they can occur occasionally to frequently for generally short durations of time (hours).

Sediment Quality Index

National estuarine conditions, as measured by sediment quality, are rated fair to poor. The sediment quality index is based on sediment toxicity, sediment contaminant concentrations, and the proportion of TOC in the sediments. About 13% of sediments in the nation's estuaries received a poor rating for one of these index components (Figure 2-10). The regions showing the largest proportional areas with poor condition were Puerto Rico (61%), Northeast Coast (16%), and West Coast (14%) estuaries. Although there are no areal estimates for poor sediment conditions in the Great Lakes, non-probabilistic surveys of that region conducted locally resulted in sediment quality being given a poor rating.

Sediment Toxicity

Sediment toxicity in the nation's estuaries is rated poor. During the NCA survey, researchers determined sediment toxicity by exposing the organisms to sediments from each location and evaluating the effects of these sediments on the survival of the organisms. Sediment toxicity tests, which were conducted using the benthic amphipod *Ampelisca abdita,* showed significant mortalities associated with 6% of estuarine sediments in the United States (Figure 2-11). Sediment toxicity was observed most often with sediments from West Coast (17%) and Northeast Coast (8%) estuaries. This indicator does not have a fair category; sediments were determined to be either toxic (poor) or non-toxic (good).



A sub-bottom profiler allows geologists to get data about the seafloor and the structure below. (photo: Dan Blackwood, USGS)

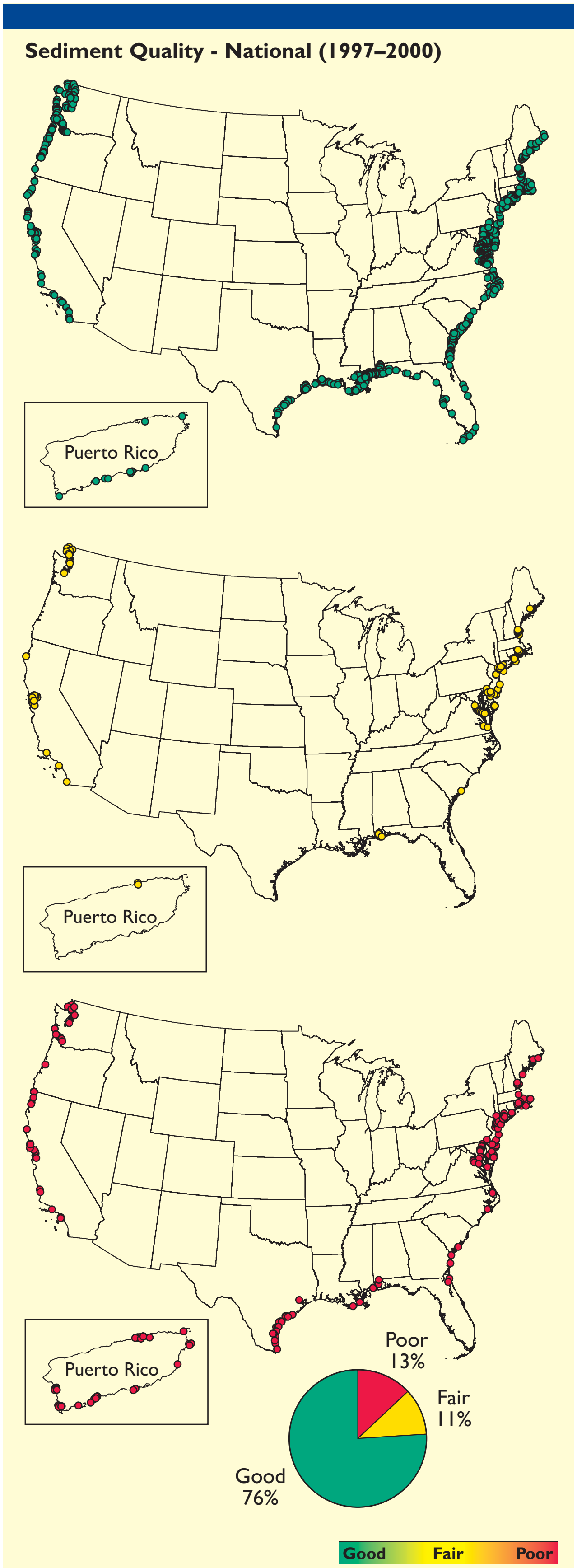


Figure 2-10. National sediment quality index data (U.S. EPA/NCA).

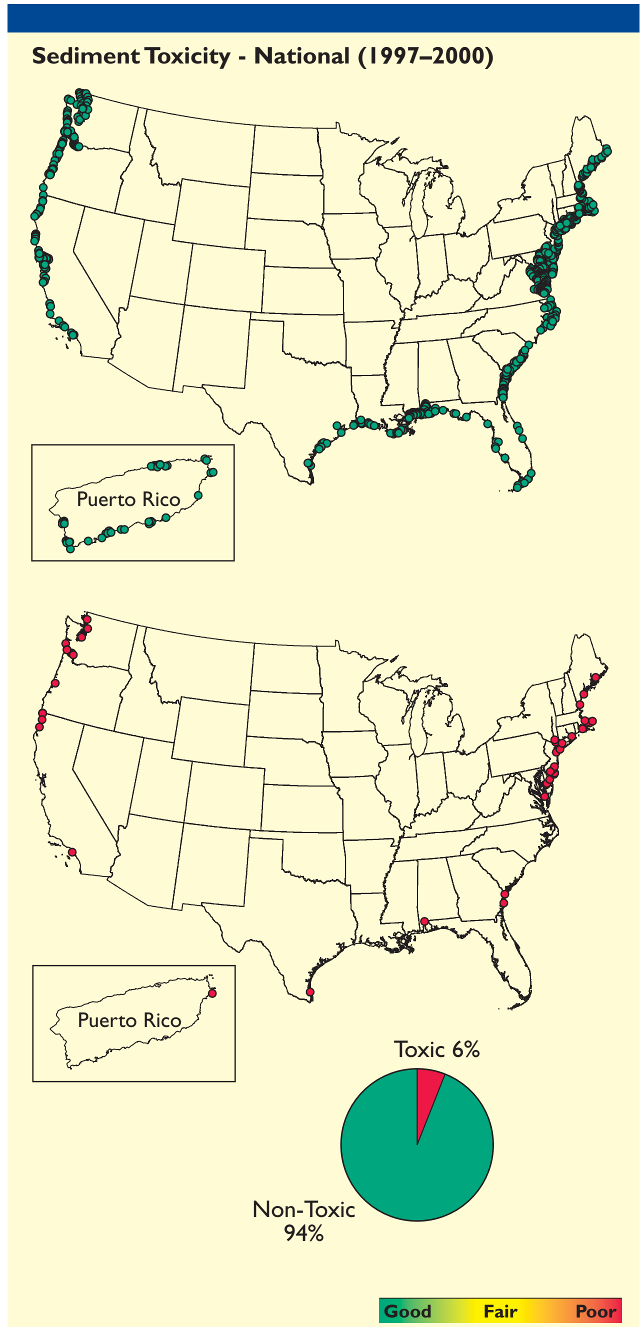


Figure 2-11. National sediment toxicity data (U.S. EPA/NCA).

highlight

A Report to the Nation on the Condition of Coral Reefs

In 1998, growing concerns for the health of coral reefs prompted the issuance of a Presidential Order (E.O. 13089) for the protection of coral reefs, establishing the U.S. Coral Reef Task Force (USCRTF) and requiring a report to the nation every two years on reef condition.

The United States has jurisdiction over tropical coral reefs that cover an estimated 7,607 square miles. In the Atlantic and Caribbean, these reefs include shallow-water coral reefs off Florida, Puerto Rico, the U.S. Virgin Islands, and the Navassa Island National Wildlife Refuge near Haiti. In the Pacific, they include extensive coral reefs off the Hawaiian archipelago, American Samoa, Guam, the Northern Mariana Islands, Wake Atoll, and six remote National Wildlife Refuges. The Pacific Freely Associated States (Republic of Palau, Republic of the Marshall Islands, and the Federated States of Micronesia) have some of the richest coral reefs in the world, covering an estimated 7,250 square miles (Wilkinson, 2002). Once U.S. protectorates, and now associates through formal pacts, these states asked to be included in U.S. coral reef activities.

Scientist conducts coral reef survey (James Maragos, USFWS).

Since the issuance of E.O. 13089, the first required biennial report, *The State of Coral Reef Ecosystems of the United States and Pacific Freely Associated States: 2002* (Turgeon et al., 2002), has been published. In 2000, the USCRTF issued its *National Plan for Action to Conserve Coral Reefs* (National Action Plan) that called for a mapping and monitoring program to help assess the condition of U.S. coral reefs. Since then, Congress has appropriated substantial funding each year for coral reef conservation. In addition, the Coral Reef Conservation Act of 2000 further integrated international, federal, state, and territorial agency efforts to map, monitor, conduct research on, restore, and manage the U.S. coral reef ecosystems.

To provide reliable assessments of reef health, the National Action Plan called for the mapping of all shallow-water reefs by 2009, the establishment of a nationally coordinated coral reef monitoring network, and the initiation of new monitoring to fill information gaps. Presently, 46% (6,894 square miles) of U.S. shallow-water coral reef habitats have been surveyed. Digital maps are available for Puerto Rico, the U.S. Virgin Islands, Hawaii (http://biogeo.nos.noaa.gov/), and much of the Florida Keys. NOAA has awarded cooperative grants each year since fiscal year 2000 to state and island agencies to build local capacity and fill gaps in monitoring. NOAA also awarded grants to the Pacific Freely Associated States in fiscal year 2002. Data collected under these grants and data from the National Coral Reef Monitoring Network (http://coris.noaa.gov/) will be the basis for the next biennial report on coral reefs in 2004.

Atlantic Coast Environmental Indicators Consortium

The Atlantic Coast Environmental Indicators Consortium (ACE INC) is developing broadly applicable, integrative indicators of ecological condition, integrity, and sustainability across four distinct and representative estuarine systems on the Atlantic coast of the United States. These estuarine systems include the nation's two largest estuarine complexes, the Chesapeake Bay in Maryland and Virginia and the Albemarle-Pamlico Sound in North Carolina; a small estuary, the Parker River, situated in the Plum Island National Science Foundation Long-Term Ecosystem Research (LTER) site in Massachusetts; and a river-dominated system in the southeast Atlantic Bight, the North River Inlet in South Carolina. These sites are representative of three primary producer bases (intertidal marsh—Plum Island and North Inlet; plankton dominated—Chesapeake Bay and Albemarle-Pamlico Sound; and seagrass dominated—portions of Chesapeake Bay and Albemarle-Pamlico Sound). They also have ongoing, long-term water quality and/or habitat monitoring programs in place that provide data for indicator development and testing. These systems each contain both pristine and impaired waters.

Because different types of coastal systems likely differ in their response to man-made or naturally induced stresses, a framework is required to assess status and to predict responses for each of the major system types. ACE INC is working to produce concise and accurate representations of ecosystem function and health, based on key variables, to detect trends in ecosystem health and to use indicators to predict the effects of human actions versus natural variability across a variety of systems, both regionally and nationally. ACE INC defines an indicator as a sign or signal that relays a complex message, potentially from numerous sources, in a simplified and useful manner. An ecological indicator is a measure, an index of measures, or a model that characterizes one or more critical components of ecosystem structure and function. With a foundation of diagnostic research, an ecological indicator may also be used to identify major ecosystem stress (Jackson et al., 2000). The present lack of established regional and national bioindicators, despite extensive monitoring at thousands of sites nationwide and specific community efforts to develop bioindicators, is testimony to the magnitude and complexity of the task. Prior efforts to achieve this goal have suggested that the most promising avenue to success is to link theoretical models with empirical relationships.

Current ACE INC research activities address the following primary objectives:

- Use remotely sensed data and time-series information on key water quality and habitat condition variables to enhance the archive of existing data for these systems
- Apply detailed knowledge of ecosystem structure and function to analyze the existing data archive and develop candidate indicators
- Test the ability of these indicators to gauge ecosystem health and clearly detect trends resulting from both natural variability and man-made stresses in multiple estuaries.

The ACE INC research plan includes the following tasks:

- Development of indicators for microalgal and macrophyte functional groups that control much of estuarine and coastal primary production
- Development of indicators for plankton and fish community structure (organization) and function, specifically indices that relate to trophic transfer and sustainable higher trophic levels
- Coupling of biological indicators with physical-chemical and remote sensing assessments of ecosystem function, trophic state, and change
- Development and application of indicators within a national coastal indicator framework (EPA Estuarine and Great Lakes Ecological Indicators [EaGLe] Program).

ACE INC is examining the indicators that form the backbone of monitoring and modeling efforts for ecosystems, regional and national water quality, habitats, and living resources. These indicators are used to calibrate and ground truth aircraft and satellite remote sensing of estuarine and coastal resources in terms of plant community structure, function, and ecological health. ACE INC is linking phytoplankton, marsh, and seagrass proxies with metrics of trophic structure to provide indicators for the status of living resources.

For more information on ACE INC, visit http://www.aceinc.org.

Status and Trends of Chemical Concentrations in Mussels and Oysters in the United States

NOAA created the NS&T Program to assess the impact of human activities on the quality of coastal and estuarine areas. In 1986, NS&T's Mussel Watch Project began to monitor chemical contamination by analyzing mussel and oyster tissues collected at fixed sites throughout the coastal United States. The term "Mussel Watch" usually refers to a program that uses mollusks as environmental sentinels to monitor chemical contamination. Mollusks are good indicators of contamination because they concentrate chemicals from their surroundings in their tissues. This makes chemical analyses an integrated measurement of contamination over time, rather than a snapshot. Measurements of chemical contaminants concentrated in mollusk tissues are also less prone to error than measurements of lower concentrations of contaminants in water.

The NS&T sites for the Mussel Watch Project were chosen to be representative of their surroundings. Because the sites must support an indigenous community of mollusk, the sites were not selected randomly and were not located in "hot spots" directly influenced by particular sources of contamination. Details on the NS&T sampling strategy, site and species descriptions, quality assurance methods, chemical methods, data analysis information, raw data, and a list of NS&T publications available on the Internet can be found at http://nsandt.noaa.gov.

Table 2-1. Spearman correlation coefficients between molluscan concentration and the number of people living within 12 miles of each site, as per 1990 U.S. Census Bureau data. For silver, copper, and zinc, concentrations in oysters must be analyzed separately from those in mussels because oysters naturally accumulate those elements to a much greater extent than do mussels.

Chemical	Spearman Correlation Coefficient
Total PCBs	0.623
Lead	0.598
Total organotins	0.585
Total chlordane	0.598
Total DDT	0.553
Total HMW PAHs	0.520
Zinc (oyster)	0.486
Silver (mussel)	0.458
Total PAHs	0.473
Copper (mussel)	0.288
Total LMW PAHs	0.252
Copper (oyster)	0.193
Chromium	0.181
Mercury	0.179
Zinc (mussel)	0.174
Total dieldrin	0.153
Silver (oyster)	0.044
Arsenic	-0.024
Nickel	-0.107
Selenium	-0.140
Cadmium	-0.312

Distributions of Concentrations

The Mussel Watch Project samples more than 220 sites regularly. In 1990, it sampled 214 sites, and the sampling results, together with 1990 U.S. Census Bureau data, illustrate a trend in the distribution of chemical concentrations that has persisted throughout the program. Table 2-1 lists correlations between chemical concentrations and the number of people living within 12 miles of a site. There are fairly strong connections between human population density and chemical concentrations in oysters and mussels for total chlordane, total DDT, total PCBs, total butyltin, total high molecular weight (HMW) PAHs, and lead, with Spearman correlation coefficients that are greater than 0.5 (Table 2-1). These findings are not surprising. The first four chemicals are synthetic chemicals whose concentrations would be zero in the absence of human activity. Although total HMW PAHs and lead would normally be found in mollusks, their present concentrations are almost entirely due to human actions. For total dieldrin, total low molecular weight (LMW) PAHs, and the elements silver, mercury, and zinc, the national-scale correlations are low, but more than 40% of the high concentrations (those above the 85th percentile) are found among the 15% of sites with 800,000 or more people living within 12 miles. For other elements, there was no evident tendency for high concentrations to be driven by human actions.

Trends

The national trends in contamination for each chemical measured in the Mussel Watch Project have been described in various publications and on the Web. For each chemical, the national-scale trends have shown either a decrease or no trend at all over the last decade. The only trace element to show a trend (decrease) has been cadmium. All the chlorinated organic compounds whose use has been banned have been showing a decrease. The results for organic chemicals for 1986 through 2002 are shown in Figure 2-12. All the chlorinated compound concentrations continue to show statistically significant decreasing trends, and at this point, there are also evident decreasing trends for LMW and HMW PAHs.

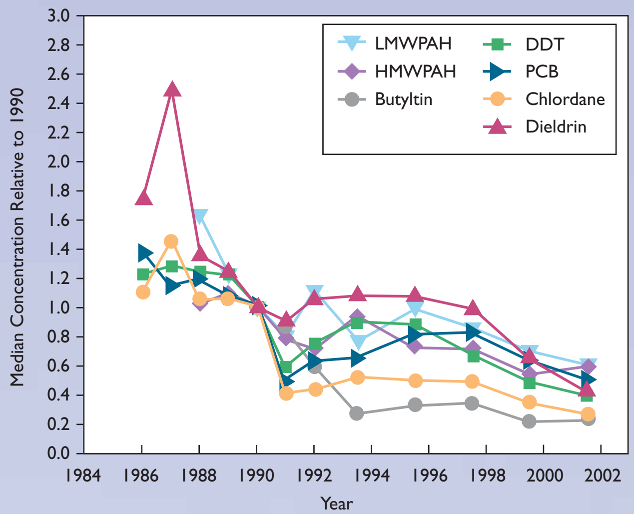


Figure 2-12. Trends in contaminants concentrations measured in NOAA's Mussel Watch Project since 1986 (Developed by NOAA for NCCR II).

Concentrations above Public Health Advisories

The intent of the Mussel Watch Project is to monitor the status and trends of coastal contamination, regardless of whether chemical concentrations present a hazard to marine biota or to human consumers of seafood. One indicator of coastal condition, nonetheless, is the suitability of seafood for human consumption. The FDA prohibits the interstate shipment and sale of seafood containing more-than-specified concentrations of mercury and certain chlorinated hydrocarbons. FDA guidelines also suggest that mollusks not be consumed if concentration limits are exceeded for chromium, nickel, lead, cadmium, and arsenic. Among the 4,000 mussel and oyster samples analyzed in the Mussel Watch Project, no mollusks collected in any year exceeded the FDA limit or guideline for mercury, chromium, nickel, or arsenic. For chlorinated hydrocarbons, only total PCBs at the Angelica Rock site in Buzzards Bay, Massachusetts, exceeded concentration limits. The limit for cadmium (for humans eating shellfish at the 90th percentile consumption rate) was exceeded in 1991 at the site on Lake Ponchartrain in New Orleans, Louisiana. In several years, mollusks at 36 of the sites had lead concentrations that exceeded the 0.8 µg/g wet weight guideline for children consuming mollusks at the 90th percentile rate. Fewer sites had lead in excess of the 1.4 µg/g wet weight limit for children consuming at the mean rate or pregnant women consuming at the 90th percentile rate. No sites had lead concentrations in excess of guidelines for adult consumption.

The guidelines set by EPA for human health are generally more stringent than those set by FDA. For example, although the FDA mercury limit of 1 µg/g wet weight has not been exceeded at any NS&T site, the EPA limit of 0.4 µg/g has been exceeded at least once at 25 sites. Exceedances of the EPA guideline for arsenic depend on how much of the total arsenic in a sample is assumed to be inorganic. With an assumption of 10%, the EPA arsenic guideline has been exceeded in all samples and in all years. With an assumption that only 1% of the total arsenic is in the inorganic form (most toxic form), the guideline has been exceeded in some or all years at 47 sites. Major differences between EPA and FDA limits are evident for dieldrin, total PCBs, and benzo(a)pyrene, the last of which has no FDA limit. For the 222 sites sampled in 2001 and 2002, there were 7 exceedances of EPA guidelines for dieldrin, 47 for total PCBs, and 45 for benzo(a)pyrene.